THE CEMENT-VERMICULITE MORTAR: A NEW MATERIAL FOR BUILDING *LANGSTROTH* HIVES

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Abstract
The expanded vermiculite is a light-weight and cheap product that, for its thermal resistance, has become a valuable insulating material, oftenly used in engineering. Regarding the similar physical properties within the wood, the hives made of cement-vermiculite mortar (CVM) have been tested in order to find out if they show also similar biological responses to the wooden hives. This study took place in a tropical region, during eight months. Standard Langstroth hives (n=20) were used in an apiary containing Africanized honeybees colonies from equal strength (one super) and queen line. The relation 1:3 cement:vermiculite was used to build the CVM hives. The CVM colonies were compared with control colonies (wooden made) in a completely randomized design, with two factors (beginning and end of the study, with and without bees) and 5 repetitions/treatment, which were used in order to test the colony performance patterns: thermal control (^oC), flight activity (bees/5 min), area of wax comb production and storage of food (cm^2), weight of the super, honey collected (kg) and its chemical analysis. The construction of the CVM hives was simple, but its management demands a certain care. The standard CVM hive (2 supers) weights about 21.66 kg and its cost requirement (US$13) was 35% cheaper than the wooden hives cost. There were no significant differences between the hives performance (P≥0,05). The honey production and the honey quality were similar (P≥0,05). Although the experiment time was restricted, the results allow us to recommend this new material (CVM) to small or poor beekeepers, to regions that need wood extraction prevention and to tropical regions. For it cannot be transported, the CVM hives must not be used for migratory activity. CVM hives have been studied for two years now, and more time is needed to further observations.

Keywords*: type of material / hive / honeybee / tropical beekeeping*

Introduction

In natural conditions, the honey bees build a nest in different places as piles of stones, hollow trees, holes on the ground, and others, trying to protect themselves against wind, rain, fire, natural enemies, etc. According to CRANE (1994), ancient beekeeping make hives of wood and bark, of earthenware, from stalks of fennel plants, of dung, of bricks, from a hollow trunk, vessels, etc. In order to develop new types of hives and improve honey bees production, as well as man job, beekeeping has created new technologies. The *Langstroth* hive, created by Langstroth em 1852, has taken advantages of the other models. Preferably, this model has been built from wood, however, beekeepers has also made this hive with others type of material (COUTO & COUTO, 1996). The wooden hives have demonstrated to be more available to the beekeepers (WIESE, 1974; DADANT & SONS, 1975), besides offering acceptable conditions, allowing their dispersion worldwide.

At the moment, *Langstroth* wooden hive presents certain problems in its maintenance and depreciation. Its cost is high at the beginning of the bees management and do not encourage the production, especially in some regions where the beekeeping industries did not established yet. In tropical climates, the life of wooden hives parts is shortened by dry rot, termite infestation, warping, casual burning, or when they are moved to ground level (HOBSON, 1983). Another point is that most of woods for building the hives are not available on the trade center and the utilization of some is illegal.

Considering the abusive use of commercial wood, it is important to emphasize that the publication of the diversity loss numbers and environmental destruction bas been alarming, such as the Atlantic Forest in Brazil. According MORELATO & HADDAD (2000) during five hundred years this forest has been damaged and restricts just to 7,6 % of its original size, with remarkable extinction of many animal and vegetal species.

In exchange of wood, HOBSON (1983) has suggested the ferrocement hive, more resistant and cheaper than the wooden hive. SOARES & BANWART (1989) have used the Fibercol hive, made of fiberglass, despite to be more expensive, is appropriate to beekeeping.

In 2000, the cement-vermiculite mortar hive was developed by some researchers as an alternative material for building *Langstroth* hive, regarding the similar properties with the wood. NEVES (2002) verified that the broodnest temperature and flight activity were similar in cement-vermiculite mortar and wooden Africanized honeybees nucleus.

This research was carried out for testing the hypothesis that the cement-vermiculite mortar hive shows similar biological responses to the wooden one. The objectives were i) to verify if there is intranidal thermal homeostasis in Africanized honeybees colonies and their time perseverance; ii) to verity if the thermal homeostasis could modify the foraging performance of the workers bees; iii) to verify honey quality and composition.

Materials and Methods

The survey was carried out from January to May 2002, in Rio de Janeiro State, Brazil (22º45'S and 43º41'W, 33 m high, AW climatic type (according Köepen classification). This region presents some native and cultivated flora. The average production is around 10 kg of honey/hive/year.

During the experiment, for knowing the melliferous flora, these plants were vouched, when they are high in floral density and abundance of bees.

The hives were installed at random on apiary, 2 m from each other, located in the north direction. There were used Africanized honeybee colonies (*Apis mellifera)*. At first, virgin queens were introduced in five combs nucleus and fertilized in the air by Africanized males. The experiment began when the bee colonies received the supers, and for this, these colonies were homogenized regarding the brood and food.

The experiment was carried out in a completely randomized design, with five repetitions in the split plot scheme. The variance analysis was accomplished on the following way: the factors were type of material (wood and cement-vermiculite) and settlement type (boxes and hives, without and with bees, respectively). They were arranged in main plots and the factor harvest time (beginning and end of the study), as subplots. Each beehive represented an experimental unit.

The wooden hives were obtained from beekeepers market. All of these hives were made of pinewood, 2 cm thick, a two coat of yellow (nests) latex paint and white (supers).

The mould must be carefully constructed to follow the standard dimensions of 10-frame *Langstroth* cement-vermiculite mortar (CVM) hive, which is reusable, and can easily made from scrap wood. For making easy the plate removal, the moulds were moistened and recovered with vegetal oil. The vermiculite used for the CVM hive was medium grain, and the relation was 1:3, cement:vermiculite according to RODRIGUES (1998). The type of the cement was CP II F 32. Both dry components were placed in a recipient and they were mixed with enough water to get a mixture. The cement mortar was poured into the moulds; they were kept in a shaded place for two days without sprinkling and three days with water sprinkling twice a day, for avoiding retraction gaps. On the ninth day, the plates were carefully removed, unscrewing the moulds. The CVM hive was setting using simple gap screw, 3.5 mm x 1 ¾" and glue. These boxes were painted with the same color as the wooden ones.

Weekly, climatic conditions were measured: external temperature (^{o}C), relative humidity (%), solar radiation (Vernon standard temperature ^{o}C), in regarding of sun and shadow, and wind speed at 7:00 and 10:00 o'clock a.m., 1:00, 3:00 and 5:00 o'clock p.m.

Broodnest and super temperature were measured using a digital thermometer, connected to a copper thermocouple, 35 cm long, introduced into a 1.5 mm hole placed in the center part of the nest and super. These data reading were bimonthly, at 7:00 and 10:00 o'clock a.m. and 1:00, 3:00 and 5:00 o'clock p.m. For evaluating bee flight activity, the workers were scored at the entrance of the hives, for five minutes, twice a day, at 8:00 o'clock a.m. and 4:00 o'clock p.m., once a week. To estimate honey bee colony strength it was measured the area of comb and food (honey and pollen) area (cm^2), using a grid of 2.5 cm squares into a *Hoffman* frame, according to TOOD & REED (1970), AL-TIKRITY et al. (1971). The super weight was read at the end of the flowering according to MCLELLAN (1977), it was measured regarding only the wax production and the food in the combs. The honey was collected, extracted from the combs weighted and samples from each treatment were obtained. These samples were submitted to chemical analyses, such as: Lund Test, reduced sugars, sucrose, pH, acidity, refraction index, Brix, humidity and macro and microminerals analyses (Ca, Mg, Mn, Fe, Zn, Cu, Cr, Co, Ni, Al, Cd, Pb).

The averages of these variables were compared by the Tukey Test. The internal temperature and the flight activity were also submitted to the analyses of Correlation of Pearson, in relation to the climatic conditions. The statistical analyses was accomplished with software SAEG version 5.0.

Results

During the experiment the mean external temperature was 29,83 ± 2,48 and January was the most humid month (74% RH). *Eucalyptus* spp. (Myrtaceae) and *Vernonia beyrichii* (Asteraceae), have showed high floral density and abundance of the bees, could be responsible for food storage.

The standard CVM hive (two supers) weights about 18,47 ± 0,24 kg and its cost requirement was US$13.

As much as in the nest or in the super, the honeybee colonies regulated the brood nest temperature, in CVM and wooden hives. Figure 1 shows the broodnest temperature in the CVM and wooden hives, regarding the external temperature and relative humidity. The mean broodnest temperature for the wooden hive was 35.98 ^{o}C ± 1.1 and for CVM hive was 36.28 ± 1.87 ^{o}C, ranging from 33.92 ^{o}C to 37.94 ^{o}C for the wooden hive and, from 32.40 ^{o}C to 39.83 ^{o}C for CVM hive. There were no significant differences between the broodnest temperature of the hives, neither their interaction ($P \geq 0.01$). There were differences between hives and boxes and their interaction ($P<0.01$) (Table I). The mean internal temperature of the super for wooden and CVM hive were respectively: 35.97 ± 1.54 °C and 35.17 ± 2.2 °C, ranging from 31.60 °C to 38.16 °C, and from 29.62 °C to 39.60 °C during the experiment.

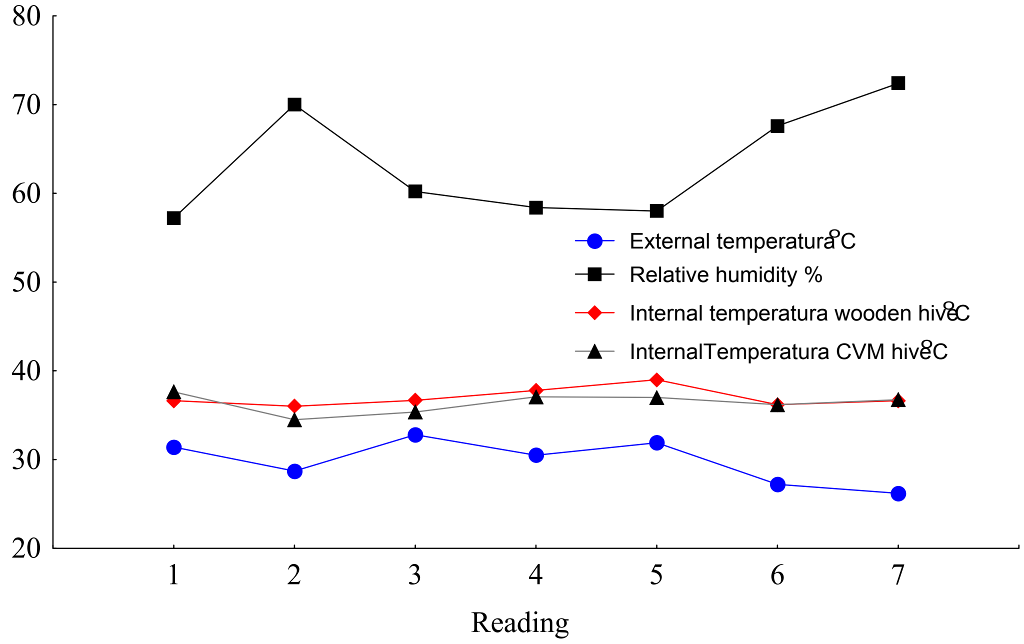

Figure 1 - Internal thermoregulation from Africanized honey bees in the cement-vermiculite mortar and wooden hives, at variations of external temperature and relative humidity.

Table I

Mean internal temperature nest and super (°C) in *Langstroth* wooden and cement-vermiculite mortar (CVM) hives, at the beginning and ending of the experiment.

Season	With bees	Without bees	With bees	Without bees
	Wooden nest		CVM nest	
Beginning	36,44Aa	32,27Ab	35,83Aa	32,36Ab
Ending	34,53Aa	29,23Bb	36,75Aa	30,37Bb
	Wooden super		CVM super	
Beginning	35,29Aa	31,28Ab	35,50Aa	31,44Ab
Ending	34,57Ba	30,55Bb	33,39Ba	30,68Bb

Capital letters were compared in columns and small letters in lines. Means followed by same letter are not significantly different by Tukey Test at the 5% level of probability.

In both CVM and wooden hives, the broodnest temperature and external humidity correlated negatively (linear coefficient, r^2 = -0.73), and positively with Vernon standard temperature at shadow (r^2 = +0.81) ($P<0.05$). Internal temperature of the super and external temperature correlated positively, and also, Vernon standard temperature at shadow and at sun (r^2 = +0.92, +0.86 and +0.83) ($P<0.05$). The broodnest and super internal temperature did not correlate significantly, as well as, with external relative humidity ($P\geq0,01$).

Table II shows higher flight activity in the wooden hive during the experiment ($P<0.01$). The flight activity of CVM hive and broodnest temperature correlated negatively (r^2 = -0.83) ($P<0.05$), and no significant correlation for the wooden hive was observed. In regarding to the climatic conditions and flight activity, there was no significant correlation ($P\geq0.05$).

Table II

Bee flight activity, number of workers/5 min, in *Langstroth* wooden and cement-vermiculite mortar (CVM) hives, at the beginning and ending of the experiment.

Season	Wooden hive	CVM hive
Beginning	316Ab	234Bb
Ending	279Ab	258Bb

Capital letters were compared in columns and small letters in lines. Means followed by same letter are not significantly different by Tukey Test at the 5% level of probability.

The type of material did not affect the wax production and food storage area (P≥0.05), however there was a large variation. The same was observed with the weight of the supers and ripe honey (Table III). The quality of the honey was guaranteed in wooden and CVM hives samples (P≥0.05). Table IV shows the macro and microminerals analysis.

Table III

Wax production, food storage (honey and pollen) (cm^2), mean weight of combs and weight of honey collected (kg), from *Langstroth* wooden and cement-vermiculite mortar (CVM) hives.

Treatments	Wax Production (cm^2)	Food Storage (cm^2)	Weight Combs (kg)	Weight Honey (kg)
Wooden Hive	36.9932 a	31.9891a	8,49a	4,13a
CVM Hive	19.5907[a]	21.2883 a	9,16a	3,47a

Means in columns followed by same letter are not significantly different by Tukey Test at the 5% level of probability.

Table IV

Macro and microminerals (ppm) in the honey collected from wooden and cement-vermiculite mortar (CVM) hives.

Type of material	Ca	Mg	Mn	Fe	Zn	Cu	Cr, Co, Ni, Pb	Al	Cd	Si
Wood	14,9	7,83	0,754	1,34	0,271	0,045	*	0,193	0,298	1,29
CVM	16,1	7,96	0,758	1,43	0,199	0,086	*	0,244	0,063	1,22

** tenor of the element below the limit of detection of the used technique*

Discussion

CVM box can be easily made using basic carpentry hand tools. The removal of the plates from the moulds and their setting up mean a loss around 5% of the plates. In spite of the ferrocement box, the CVM weight is lower and its cost, without frames, was 56% cheaper than the wooden pine box cost.

The CVM box is fragile and the edges can suffer damages during the management by the beekeepers. Cover and bottom board were more susceptible to be broken. Wooden boxes have presented gaps, warping; they were more susceptible to environmental conditions.

The CVM box tolerated on acceptable way the weight variations of the swarms. The absence of absconding, swarming, disease and pest occurrences, the aggressiveness tolerable of the Africanized honey bees, were evidences that these materials showed to be appropriate as shelters for bee colonies.

The external temperatures reported in this experiment have been higher than the interval considered optimal for European honey bees colonies, ranging from –10 ^oC to 15^oC, to save energy to the thermoregulation of the colony (SOUTHWICK & MORITZ, 1992). In tropical climates, there are no reports about the relationship between temperature and the energy metabolism for Africanized honey bees colony.

The broodnest temperature of the CVM and wooden hives was relatively stable with the Africanized honey bees (Figure 1), even at variations of the climatic conditions. This temperature remained above the external temperature (HEINRICH, 1993), being evident when has been compared with internal temperature from the boxes and the hives (Table I). This fact reveals an independent broodnest temperature, explaining the absence of correlation with external temperature. This result agrees with MYERSCOUGH (1993) reports, but disagrees with TOLEDO & NOGUEIRA-COUTO (1999) reports, that verified positive correlation.

The internal temperature of the super was similar to the broodnest temperature (Table II). The positive correlation between internal temperature and external temperature, and solar radiation showed that Africanized honey bees colonies were able to support these changes. This correlation can be explained by the presence of the honey, the main compound of the super, presenting high thermal conductivity (CRANE, 1976), so that can increase the interval of the internal temperature.

The negative correlation between external humidity and broodnest temperature shows that the bees were able to control it inside the nest (TOLEDO & NOGUEIRA-COUTO, 1999). The internal temperature of the super was independent from the external humidity, probably because of the presence of honey, as a good thermoconductor.

In both brood nest and super eusocial bees were successful to keep the temperature constant, known as social homeostasis, an important behavior for the survival of these colonies (LINDAUER, 1964; HEINRICH, 1994). At external temperatures, 21 and 38 ^oC, it was observed that mean internal temperatures of the CVM and wooden hives at 35.98 ^oC and 36.28 ^oC for nest, 35,39 ^oC and 35.17 ^oC for super, are relatively close to those observed by LENSKY (1964) at 37.6 ^oC, by SAKAY (1974) at 35 $\pm$ 1.0 ^oC, by MIWNICK & MURPHEY (1974) at 34 ^oC and by TOLEDO & NOGUEIRA-COUTO (1999) at 33.7 ^oC. NEVES (2002) reported lower average in Africanized honey bees CVM nucleus.

It should be still considered on thermal evaluating the internal temperature interval. According to SEELEY & HEINRICH (1981), the optimal temperature variation for the broodnest of European honey bees is from 32 to 36 ^oC, to FREE (1980) is from 34 to 35 ^oC to KRAU et al. (1998) is from 30.7 to 37 ^oC. BRANDEBURGO et al. (1986) reported to Africanized honey bees from 34.2 to 36.4 ^oC, and TOLEDO & NOGUEIRA-COUTO (1999), from 31.1 to 35.8 ^oC. Sometimes during the experiment, the variation of the broodnest temperature overcame 36 ^oC, around 2^oC more for wooden hive and around 4 ^oC more for CVM hive, it can be an important thermal stress. According to HIMMER (1927), 1 to 2 ^oC over 36 ^oC for a long time has hardly damaged the larval metamorphosis of the bees, brood development, besides reduce the adult lifetime (HEINRICH, 1980). SOUTHWICK & MORITZ (1992) reported as critical limit the permanent and high nest temperature at 35 ^oC, always over the dew temperature, so that in wet conditions it increases the effect of temperature (AYOADE, 2001) and the broodnest thermoregulation. So, under thermal stress a group of workers can be required in order to combat overheating the colony.

The forager activity in CVM hives was lower than in wooden one (Table III). It could mean that more bees might require controlling the internal temperature that has eventually ranged out the optimal limit. Probably it can be, when it is verified the flight activity and broodnest temperature was correlated negatively (r^2 = -0,83). NEVES (2002) did nor report any difference on flight activity between CVM and wooden Africanized honey bee nucleus.

Regarding that the social behavior should reestablish the thermal homeostasis (Fig. 1), the cost for this control can be lowered and subtract the amount of food that enters in the honey bee colony. SOUTHWICK & MORITZ (1992) reported that 580 calories are lost to each gram of evaporated water produced by the bees. So, the smallest flight activity in CVM hives can represent more bees for thermoregulation, what would be a negative aspect for this hive. Another factor to explain the smaller flight activity would be the reduction of the population, what would also be a negative aspect. NEVES (2002) reported smaller brood area in Africanized honey bee CVM nucleus than the wooden one.

It was not observed any kind of problem in relation to the internal temperature of the boxes (Tables I and II). So, the probability of increase of the broodnest temperature at the CVM hive it can be due to the greater water absorption capacity by vermiculite (DEER, 1996). During wet conditions, the water into the hive can slowly evaporate and difficult the evaporative cooling by the bees, which is an important thermoregulation mechanism for the honeybee colony (LINDAUER, 1964; SOUTHWICK, 1992). The presence of unripe honey, with high water level, can demand more bees to take away the excess of humidity in the colony, caused by its dehydration (MORSE, 1973; VAUGHN, 1977). According to LINDAUER (1964), a considerable amount of bees must remain inside the colony for helping cooling, in order to control the internal temperature. During the experiment the presence of unripe honey was prevalent in the super, which dehydration can increase the thermal stress of the colony, reduces the flight activity for cooling, or it can be a signal of the decrease of colony strength. Both of them, could decrease the food amount (VAUGHN, 1977).

The decreased flight activity can promote another assignments inside the colony, as wax production and food storage. In these evaluations there were not observed any differences between the type of tested material (Table IV), however the variation of these results do not still allow to state if it really occurs.

Despite the mean food weight of the supers have been higher, honey collection was low. It occurred because honey from supers did not reach the ripen point and there was a decrease of the main seasonal honey flow. The honey quality was guaranteed by routine analyses and macro and macrominerals levels are below of those ones reported by CRANE (1976).

Although the experiment time was restricted, the results allow us to recommend this new material (CVM) to small or poor beekeepers, to regions that need wood extraction prevention. The biological responses were satisfactorily to keep the Africanized honeybees colonies in this hive and their confined aspects can be rectified. For it cannot be transported, the CVM hives must not be used for migratory activity. CVM hives have been studied for two years now, and to further observations more time is needed. Some tests could be performed in wet tropical environments, offering greater ventilation in the supers

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